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**ENVIRONMENTAL ASSESSMENT: TAR SAND IN SITU STEAM INJECTION
EXPERIMENT**

December 1979

Laramie Energy Technology Center
Laramie, Wyoming

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

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ENVIRONMENTAL ASSESSMENT

TAR SAND IN SITU STEAM INJECTION EXPERIMENT

for the

LARAMIE ENERGY TECHNOLOGY CENTER

Vernal, Uintah County, Utah

December 1979

U. S. DEPARTMENT OF ENERGY
LARAMIE ENERGY TECHNOLOGY CENTER
LARAMIE, WYOMING

This document is
PUBLICLY RELEASABLE

B. Steele
Authorizing Official

Date: 3/22/06

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I. EXECUTIVE SUMMARY

The U. S. Department of Energy - Laramie Energy Technology Center (LETC) intends to conduct a field experiment for the in situ recovery of bitumen from tar sand. The experimental site is located on a ten acre site approximately 6.5 miles West of Vernal, Utah. The operational phase of the experiment will last approximately six months.

The experiment will utilize steam to lower the viscosity of the bitumen and drive it into production wells where it is recovered. The recovered product will be separated into bitumen and water components using settling tank and emulsion breaker. The produced bitumen will be stored on site or burned as fuel. The produced water will flow through an environmental sampling tank and into a holding pond. From the holding pond the water will either be treated and recycled into the process or disposed of at a State of Utah approved site.

Due to the small scale of this experiment, the impact of the proposed action will be minimal. The number of employees will range from 2-20, peaking during construction and actual site operation, and minimum after completion of the experiment.

There will be no violation of air quality standards due to the experiment. The major source of emissions will be an 18MM BTU steam generator. Minor sources include vehicular emissions and a 4.5MM BTU steam boiler.

The experiment will not involve any surface discharges. Steps have been taken to ensure that any spills will be localized.

The experiment will have no impact on groundwater of the region. No mobile water has been found on site in the tar sand formation to be used during the experiment. Shales of low permeability overlay and underlay the tar sand formation to prevent transport to either the alluvium or underlying sands and shale. The nearest down dip water wells are approximately eight miles from the site.

All wastes generated by the experiment will go to a controlled waste disposal facility. Sanitary wastes will be handled by an on site septic tank and leach field, or removed by licensed field service companies.

Impact on local biological life will be minimal. The experiment will have no effect on aquatic habitats. The site is arid and situated approximately 3.5 miles from the nearest perennial water source.

The major impact on vegetation will be surface disturbance and removal of vegetation. No critical habitat will be lost. Topsoils are being stockpiled for reclamation purposes.

The site is only ten acres and this small loss of habitat should have little effect on wildlife of the area. Some small rodents may be lost. The vast area of sagebrush habitat will allow the displaced animals to relocate without a great deal of stress or competition.

No rare or endangered biological species will be affected by the experiment.

The experiment will have no known effects on employees or the general population. No serious effects on aesthetic, recreational, or cultural resources is expected.

II. PURPOSE AND NEED

"Tar Sand" refers to consolidated or unconsolidated rocks with interstices that contain very viscous to solid bitumen which, in its natural state, cannot be recovered by primary petroleum methods. Other terms applied to this material have included "bituminous sandstone," "oil-impregnated rock," "oil sand," and "rock asphalt."

In the late 1960's, the United States tar sand bitumen resource was estimated to be between 2.5 and 5 billion barrels scattered among 22 states. Known deposits in 1979 in five states are estimated to be nearly 30 billion barrels of oil, with about 29 billion barrels in Utah. Six of the deposits in Utah contain from 1 to 16 billion barrels of oil. Four of these deposits are in the Uinta Basin and contains up to 11 billion barrels of low sulfur oil. These are prime targets of current interest in developing production from tar sand.

The objectives of the Department of Energy (DOE) Tar Sand RD&D Program are:

1. To determine the probable commercial potential of domestic tar sand and the technology requirements for recovery of the oil.
2. To develop and test in situ thermal recovery technology and evaluate its technical and economic feasibility along with alternate extraction techniques.

The program directly supports a major goal of the DOE Petroleum Program: to increase domestic production and reserves of oil and gas, including heavy oil deposits and tar sand.

As a result of the considerable increase in the estimated Utah tar sand resource, the DOE Laramie Energy Technology Center (LETC) initiated a project in 1971 to analyze the physical characteristics of significant tar sand deposits and to evaluate the application of in situ thermal methods for recovery of oil from a Utah tar sand. Two in situ combustion field tests have been completed with successful production of bitumen. These tests were not designed to measure economic potential of the methods, but to determine technical feasibility, and to identify and solve problems affecting use of the methods.

The first combustion experiment (LETC TS-1C) began in November, 1975 and terminated 3½ weeks later. The total production was 65 bbl. of bitumen and 165 bbl. of water.

Approximately three acres of land was cleared and leveled. Electricity and telephone service were brought into the site from nearby lines. An exist-

ing vehicle trail approximately one mile long was graded and leveled to provide access to the site.

A total of 15 wells was drilled in a pattern 120-feet long and 40-feet wide. Production water was sampled during the experiment and in the wells six months and one year after the experiment. The results showed a marked change in the chemical constituents of the residual water. Bicarbonate and sulfate levels increased while total nitrogen, ammonium, and chemical oxygen demand decreased.

The second combustion experiment (LERC TS-2C) began in August, 1977 and concluded in February, 1978. The total production was 580 bbl. of bitumen and 600 bbl. of water.

An additional acre of land was cleared and leveled. No new utility or access corridors were constructed. A total of 22 wells was drilled into a pattern 120-feet long and 40-feet wide.

Process water was sampled and analyzed for chemical constituents. The organic constituents were extracted from the water and analyzed by GC-MS. These organics were found to be mainly low molecular weight carboxylic acids with some phenols and pyridines also present.

With the basic technical feasibility of the in situ combustion recovery technique shown, LETC is now preparing for similar small scale tests using an alternative thermal method, steam drive. Steam drive appears to be a viable process for application to tar sand because of its recent successful use for recovery of heavy oils. However, there are potential problems with its use to recover bitumen from Utah tar sands: scarcity of water in the area, lack of adequate injectivity for acceptable rates of heating, and possible condensation ahead of the steam front with plugging of permeability. These problems will be explored, and basic technical feasibility data on the steam drive process will be obtained. Subsequent testing of in situ thermal processes will then be guided by thorough engineering evaluations of the data on both the steam and combustion processes.

The outputs from the Tar Sand RD&D Program are expected to satisfy the key technical needs of:

- o In situ thermal recovery of oil
- o Environmentally acceptable waste management and control

The RD&D Program has been planned to develop and evaluate processes for recovery of oil from tar sand. Experimentation and evaluation of in situ thermal recovery techniques in both the laboratory and the field are the major thrusts of the effort. Thermal methods include forward and reverse in situ combustion as well as hot fluid injection. The primary hot fluid injection techniques are cyclic steaming, steam flooding, and hot water flooding.

The first steam field test is to determine the steam injectivity in tar sand and to evaluate possible requirements for modification of the tar sand matrix to permit sustained injection and production operations.

The data obtained from the first field test will be analyzed to decide whether to continue investigations with the steam injection process for tar sand.

The eventual commercialization of oil recovery from tar sand is possible only if the process is environmentally acceptable. Although control and disposal of wastewater may be the largest environmental problem to be overcome, the air emissions and solid waste must also be monitored, characterized, and controlled. The research and development needed in this area are planned to be conducted in parallel with the field tests while assuring compliance with the environmental requirements of the regulatory agencies for the field tests.

III. DESCRIPTION OF THE PROPOSED ACTION

A. INTRODUCTION

1. Overall Description

The Department of Energy - Laramie Energy Technology Center (DOE-LETC) proposes to conduct a field experiment for the in situ recovery of bitumen from tar sand by steam injection. The experimental site is located on a ten acre tract approximately 6.5 miles West of Vernal, Utah (Figure 1). The site is located in the NW-1/4, NE-1/4, SE-1/4, Sec. 23, T.4S., R.20E, SLM, Uintah County, Utah. The tract is owned by the Sohio Petroleum Company, and is currently leased to LETC. All surrounding lands are state owned.

High temperature steam at 80% quality and 500-700 psi will be injected into the tar sand formation to lower the viscosity of the bitumen and act as a driving force to push the bitumen to the production wells where it is recovered. The operation phase will be approximately six months.

A six acre portion of the experimental site has been cleared for the experimental pattern and support operations. The pattern for the steam injection experiment (LETC TS-1S) will be two concentric inverted five spots, with the inner four production wells on a 0.10 acre pattern and the outer four production wells on a 0.25 acre pattern (Figures 2, 3).

Steam for the experiment will be produced by an 18MM BTU/hr steam generator. Steam tracing of production facilities will be produced by a 4.5 MM BTU/hr steam boiler. City water will be used for feedwater in both pieces of equipment. City water will be trucked to the experimental site by commercial hauler.

Steam will be injected into the tar sand test zone in the Rimrock sandstone member of the Cretaceous Mesaverde Formation at an average depth of 490 to 540 feet in the experimental zone (Figure 4).

Bitumen and water will be produced at the production wells in the pattern. Production is expected first in the 0.10 acre pattern and later in the 0.25 acre pattern.

FIGURE 1. TAR SAND RESEARCH AREA NEAR
VERNAL, UTAH

FIGURE 2. LETC TS-IS SITE LAYOUT

FIGURE 3. LETC TS-IS WELL PATTERN

FIGURE 4. IDEALIZED GEOLOGIC CROSS SECTION THROUGH EXPERIMENTAL SITE

The produced bitumen and water will be separated in settling tanks. The bitumen will be stored in two 300 bbl. tanks. The water will pass through a 400 bbl. environmental tank and into a 5000 bbl. holding pond (Figures 5, 6).

Produced water will be disposed of by licensed commercial oil field service companies. Some produced water may be cleaned up and recycled back into the process.

The experimental site will be shut down when it has been determined that the goals of the experiment have been realized. These goals include:

1. Determine the technical and economic feasibility of using steam injection as an in situ recovery technique in a Utah tar sand.
2. Evaluate an injection well completion scheme with a high temperature packer.
3. Evaluate several types of downhole completion schemes for the production wells.
4. Determine recycle and fuel use possibilities of produced water and oil.

The site will then be dismantled, reclaimed, and abandoned.

2. Impact Summary

Due to the small scale of this experiment, the impact of the proposed action will be minimal. The number of employees will range from 2-20, peaking during construction and actual operation, and minimum after completion of the experiment. There will be no violation of air quality standards due to the experiment. The experiment will not involve any surface discharges. The experiment will have no impact on groundwater of the region. All wastes generated by the experiment will go to a controlled waste disposal facility. The experiment will have no known effects on employees or the general population.

B. CONSTRUCTION PHASE

1. Road Construction

A road has been constructed into the field site during a previous combustion experiment. The access road to the location was prepared from existing dirt trails and improved by grading for drainage and graveling. No additional roads will be required for the proposed steam injection experiment (LETC TS-1S). The road is approximately one mile in length.

2. Utility Corridors

The existing field site uses power generated off site by Utah Power and Light. Telephone communications are used. A telephone line was brought into the site from existing lines. No other utility lines or corridors are in use.

Figure 5. Schematic of the Tank Farm for LETC TS-IS

FIGURE 6. SCHEMATIC OF THE WATER HANDLING SYSTEM FOR LTC TS-1S

3. Site Clearing

The entire ten acre site is fenced. Approximately two acres will be cleared in addition to the four acres that were cleared for the previous two experiments. The topsoil has been stockpiled and segregated. The acreage is being used for the experimental well pattern and support activities. No additional land will be cleared for the experiment.

4. Building Construction

No permanent buildings are constructed on LETC field sites. All buildings are temporary in nature since the experiments are of short duration and it is most feasible to move buildings from site to site. Those buildings already on site include a compressor building, an instrumentation building, a shop building, a production building, a washhouse, and an office. A temporary shelter may be built to house the steam generator.

Other structures on the site include a tank farm and a platform for the steam generator.

All structures will be located on land that has already been cleared for the experiment.

5. Well Drilling

Thirteen wells will be drilled, cased, completed, cemented, and connected to the steam generator, production treating equipment, and instrumentation by surface pipelines and electrical conduit. The wells include one injection well, nine production wells, and four monitoring wells (Figure 5).

A nearby corehole from previous drilling will be completed to monitor fluid migration outside of the experimental pattern. Additional groundwater-monitoring wells may be necessary to conduct expanded environmental research. The exact number and placement of wells will depend on need, timing, and funding.

6. Geologic Fracturing

One of the most important problems affecting the use of steam in the development of satisfactory in situ recovery procedures is the lack of fluid injectivity. Steam injection near the wellbore is a potential method of increasing permeability by removing bitumen. Steam injection combined with fracturing could further enhance permeability in a tar sand formation.

The LETC TS-1S steam injection does not intend to initiate any geologic fracturing of the tar sand at this time. However, if satisfactory permeability is not attained by steam injection, an attempt to create a hydraulic fracture within the pattern may be made, since the use of explosives is not anticipated. A hydraulic fracture is created horizontally through the formation by increasing the injection pressure. No other formations will be affected.

7. Equipment Installation

LETC employees and contractors will be used to construct all site structures and install equipment. LETC employees on the site number between two and ten. Contractors (less than 15) are on site for a few days at a time.

8. Housing

Contractors and LETC employees are housed in motels in Vernal, Utah. LETC employees commute to and from Laramie, Wyoming. On-site permanent housing is not required for any employees.

C. OPERATIONAL PHASE

1. Gas and Liquid Injection

Steam at 80% quality will be injected into the tar sand formation at the injection well between 532 and 582 feet below the surface. The experiment will utilize the steam drive (or steam flooding) process. Steam is injected continuously into the injection well, causing steam, hot water, and bitumen to move laterally to production wells where the bitumen and water is recovered.

2. Product Recovery

The produced mixture of bitumen and water will be recovered from the production wells by standard oil field pumping procedures. The mixture will be allowed to separate by gravity and may be treated with an emulsion breaker.

3. Bitumen Storage

The recovered bitumen will be stored on site in two 300 bbl. storage tanks. If the capacity of the tanks is exceeded, the excess bitumen will be placed in a spare 250 bbl. storage tank, burned as fuel in the steam generator, or removed to other research facilities.

4. Water Storage, Reuse, and Disposal

The recovered water will pass through a 400 bbl. tank into a 30 mil CPE lined 5000 bbl. holding pond. Some of the water will be removed for research and characterization studies.

A portion of the water may be cleaned up, and recycled through the steam generator back into the process. This recycling will depend upon the results of characterization studies on the recovered water.

The majority of the water will be removed from the experimental site by licensed commercial oil field haulers to a disposal site. An alternative to hauling the recovered water to a disposal site is the use of such water in dust control on the experimental site and access road.

5. Waste Disposal

Waste sludges will be removed from the experimental site by licensed commercial oil field haulers to a disposal site. Such sludges will be com-

posed of ambient dust and sand recovered from the process with some oil adsorbed to the sand surfaces. Common trash such as wood and paper will be hauled to the Vernal city dump by LETC employees or contractors. Human waste will be handled by a septic tank and leach field system already on the site.

Recovered process water will be disposed of by depositing it in liquid waste disposal area operated by Standard Oil of California (Chevron) and approved by the State of Utah for handling of oil production wastes. Small quantities have been used for characterization studies and research purposes. Produced water will be used for research in process water treatment and reuse schemes as part of the overall water management plan.

a. Production Water Volumes. Computer modelling on the steam injection process at the Vernal experimental site indicates a maximum water production rate of 100 BPD during the expected length of the experiment. The cumulative production of water is expected to be approximately 2000 bbl. Of this cumulative amount, 400 to 600 bbl. will be removed from the site for research purposes. The remainder will be removed to the Vernal city dump for disposal. The production amounts are summarized in Table 1.

Table 1. Production Water Volumes and Destinations

Water Accumulation/Disposal	Amount (bbl.)
Maximum Daily Production	100
Cumulative Production	2000
Removed for Research	400-600
Chevron Waste Pit Disposal	1400-1600

b. Production Water Characterization. The exact composition of the water produced by the steam injection experiment (TS-1S) is unknown. Several basis for constructing an estimation of such a composition do exist, and have been used to construct a most probable and a worst case production water. This data is summarized in Table 2.

LETC has planned extensive characterization work for the waters recovered from the TS-1S experiment. This work will provide a basis for further field experiments and present additional alternatives for handling the water produced.

6. Water Consumption

Water consumption for the steam injection experiment may be broken down into three areas: injection requirements, production requirements, and miscellaneous site use. Water will be supplied by licensed field service operators. There will be no impact on local water supplies.

a. Injection Requirements: The amount of water injected into the tar sand formation will range from 30 to 250 barrels per day (BPD). The actual amount of water injected will depend on the permeability of the formation. The maximum amount of water injected over a six month operating period will be 45,000 bbl.

Table 2. Water Characteristics for Similar Production Waters and Expected Cases for TS-1S

Constituent mg/l	Steam Lab Test			Injection	City Water	Worst Case	Most Probable
	Ave	Min	Max	Steam Test			
Calcium	8.5	7.9	8.8	420	25	400	50+50
Magnesium	0.0	0.0	0.0	520	5	500	10+10
Sodium	1.6	1.3	1.7	210	2	2000	1000
Potassium	1.1	0.1	1.7	130	0.6	130	50+50
Ammonium	9†			12		100	50+50
Carbonate	0.0	0.0	0.0	0.0	0.0	0.0	0
Bicarbonate	62	62	62	350	98	350	200+100
Sulfate	0.0	0.0	0.0	2600	8	2500	750+500
Chloride				190	3.5	190	100+
Nitrate				0.0	0.07	0.0	0
Fluoride	0.0	0.0	0.0	6.6	0.0	7	4+4
Copper	<0.01	<0.01	<0.01	0.03		0.03	<0.01
Iron	0.00	0.00	0.00	1.1		1.0	0
Manganese	<0.05	<0.05	<0.05	4.5		4	<0.05
Zinc	0.03	0.02	0.04	0.06		0.6	0.05
Nickel	<0.1	<0.1	0.1	0.4		0.4	<0.1
Arsenic	0.06	<0.02	0.09	<0.001		0.1	<0.02
Selenium	<0.005	<0.005	0.02	0.007		0.02	<0.005
Mercury	0.002	<0.001	0.002	0.002		0.007	0.002
Cadmium	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	0.03		<0.1	<0.1
Lead	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1
Silver				<0.1		<0.1	<0.1
Aluminum	0.4	<0.5	0.6	0.6		0.6	0.4
Barium			<0.5			<0.5	<0.5
Phenols	*	*	*			20	
Cyanide	<0.001	<0.001	<0.001				
Thiocyanate	<0.05	<0.05	<0.05				
Tetrathionate	<0.05	<0.05	<0.05				
Thiosulfate	<0.05	<0.05	<0.05				
Lithium	<0.01	<0.01	<0.01				
Cobalt	<0.04	<0.04	<0.04				
Molybdenum	<0.1	<0.1	<0.1				
Vanadium	<0.3	<0.3	<0.3				
Boron	0.0	0.0	0.0	0.8	0.01	0.8	0.1
pH	7.2	7.1	7.3	7.0	7.9	7.0	7.3
Conductance				4850	175		
Hardness	21	20	22	3200	83	3000	300+
Total Dis-							
solved Solids	0.0	0.0	0.0	5760	90	6000	200+
COD	800	560	940	300		2000	1000+
Total Dis-							
solved Carbon	340	177	627	318		700	300+
Dissolved In-							
org. Carbon	19	6	37	65		100	50
Dissolved Or-							
ganic Carbon	320	162	590	250		600	250+250
Dissolved Kjeld.							
Nitro.	6	3.2	9	7.7		10	8
Total Kjeldahl							
Nitrogen	18	18	18	110		120	20
Total Ortho							
Phosphate	0.7	0.4	1.0				
Oil & Grease	5	<0.1	12	90		100	50+50

†added to cations to balance anions

*interference with analytical method if no value is given, not reported

b. Production Requirements: The water required in the production phase of the experiment includes the steam tracing of production lines, fuel storage tanks, and water storage tanks as well as steam injection into the production wellbores.

The steam trace system will operate as a closed loop with nearly 100% recycle. The initial water demand is approximately 200 bbl. with system losses estimated to be less than 0.5 gallons per hour (gph). The total demand for a six month operating period is expected to be 252 bbl.

Steam injection may be used in the production wellbores to prevent produced bitumen from congealing in the bottom of the wells. Based on prior experience, the water demand for this system is expected to be 50 BPD or 9000 bbl. over a six month production period.

c. Miscellaneous Site Use: A total water demand of 50 BPD is required to support general site use and systems. This includes showers, washing, toilet facilities, and drinking water supplies.

A summary of water consumption for the steam injection experiment (LETC TS-1S) can be seen in Table 3.

7. Fuel Consumption

Fuel consumption for the experimental site will be in the form of #6 fuel oil, propane, and tar sand bitumen. The #6 fuel oil will be used to fire the steam generator. The maximum fuel consumption rate for the generator will be 45 BPD. The average consumption rate is expected to be 22 BPD.

Propane will be used to fire the steam boiler and miscellaneous space heaters around the experimental site. The propane demand of the steam boiler will be 3 gph or 12,960 gallons per six months. The estimates for propane consumption are based on actual operating data from a prior experiment.

Table 3. Water Requirements for TS-1S

Demand	bbl/day	bbl/6 mo.
Steam Generator (Avg.)	250	45,000
Steam Generator (Max.)	778	140,040
Steam Boiler ¹	200	200
Production Wells	50	9,000
Miscellaneous	50	9,000

¹The steam boiler requires only a one time demand since it operates as a closed system.

Tar sand bitumen may be blended with #6 fuel oil to fire the steam generator, not to exceed 20% bitumen. The bitumen used will be produced by the steam injection experiment and previous combustion experiments. No environmental impacts from the combustion of the bitumen will exist since the product bitumen is lower in sulfur and nitrogen content than the #6 fuel oil.

The anticipated fuel consumption for the steam injection experiment is summarized in Table 4.

Table 4. Estimated Fuel Demands for TS-1S¹

System	Fuel	Per hr.	Per 6 mo.
18X10 ⁶ BTU/hr steam generator	#6 fuel oil	100.8 gal. 39.6 gal.	10368 bbl. ² 3994 bbl. ³
4.5X10 ⁶ BTU/hr steam boiler	propane	10 gal.	15000 gal.
Miscellaneous space heaters	propane	3 gal.	8000 gal.

¹Propane data based on data from combustion experiment TS-2C

²Maximum fuel demand with no blending of tar sand oil

³Expected average fuel demand with no blending of tar sand product oil, based on 300 BPD of water demand (See Table 1).

8. Electric Power Consumption

Electric power will be used to operate and maintain various site systems. These include lighting, instrumentation, power tools, data collection, pumps, compressors, and other daily operations. Electric power is generated off site by Utah Power and Light. The consumption rate is expected to be 66,000 kwh per month, based on prior experience.

9. Summary of Emissions

The potential emissions for the TS-1S experiment are shown in Table 5. The emission potential is based on various steam injection rates on the test pattern, which determines the fuel demand of the steam generator. This basis for the various water demands has been discussed earlier and summarized in Table 5. It should be restated that the water demand of 778 barrels is for the full capacity of the 18MM BTU/hr steam generator and is a much higher demand than is expected for the TS-1S experiment.

10. Employment

Experimental field tests of steam injection to recover bitumen from tar sand will require 10 to 20 employees at one time. Most LETC employees will commute from Laramie and stay in motels in Vernal, Utah during site activities. Contract employees are also expected to be housed in Vernal.

D. POST-OPERATION PHASE

1. Shutdown

The experiment will be shutdown upon satisfying the goals of the project. Steam injection will cease and the formation allowed to equilibrate to a steady state.

Table 5. Stack Emission Rates for Various Fuel Consumption Rates

Water Demand BPD	Fuel Basis (BPD)	Pollutant	#/hr	#/day	tons/6 mo.	tons/yr.
137 ¹	10.14	SO ₂	4.18	100.39	9.03	18.31
		NO _x	2.07	49.69	4.47	9.06
		Particulate	0.32	7.71	0.69	1.40
		HC	0.04	1.01	0.09	0.18
		CO	0.09	2.13	0.19	0.39
300 ²	22.19	SO ₂	9.15	219.68	19.77	40.09
		NO _x	4.53	108.73	9.79	19.85
		Particulate	0.70	16.86	1.52	3.08
		HC	0.09	2.22	0.20	0.41
		CO	0.19	4.66	0.42	0.85
600 ³	44.39	SO ₂	18.31	439.46	39.55	80.20
		NO _x	9.06	217.51	19.58	39.20
		Particulate	1.41	33.74	3.04	6.16
		HC	0.19	4.44	0.40	0.81
		CO	0.39	9.32	0.84	1.70

¹Minimum operating conditions

²Expected normal operating range

³Maximum operating conditions.

2. Equipment Removal

All equipment will be removed from the experimental site as soon after the conclusion of the experiment as is feasible.

3. Post-Experiment Coring

Coreholes will be drilled to evaluate the effects of the experimental process. The exact areas to be cored will be determined upon evaluation of pertinent data from the experiment.

4. Abandonment of Roads

The access road will be abandoned at the completion of all site activities. The road will be abandoned in accordance with State of Utah regulations and to the satisfaction of the property owner.

5. Gases Escaping

Upon conclusion of the experiment, the tar sand formation will be allowed to return to its normal pressurized state. This will minimize the chance of gas escaping from the formation at a later time. Any gas escaping will be water vapor in air.

6. Reclamation

Planning will be necessary to determine the method of reclamation and revegetation of the experimental site. The reclamation will be done in accordance with State of Utah regulations and to the satisfaction of the owner of the property.

7. Groundwater Transport

The tar sand formation in the experimental site will be monitored for groundwater transport into and out of the experimental zone. The extent of this monitoring will depend upon the transport data collected during and after the experiment.

8. Well Abandonment

All wells to be abandoned will be plugged and sealed according to State of Utah regulations, and to the satisfaction of the property owner.

9. Workers Remaining

LETC will maintain a small number of employees (2-5) at the experimental site until such time as the site is abandoned.

E. ALTERNATIVES NOT CONSIDERED

This environmental assessment has not considered other technologies as alternatives to tar sand development. Alternatives considered are alternative methods for processing tar sand.

Among the alternatives not considered as feasible for the LETC TS-1S experiment are in situ combustion, combined combustion followed by steam injection, and a "huff and puff" steam operation where steam is injected into a well for a short period and bitumen recovered from the same well at a later time.

There are no environmental advantages for any of these alternatives as compared to the proposed action. The same conditions would exist on the surface, with the same area having to be cleared and later reclaimed. The socio-economic impacts would be the same as would the water and biological impacts.

Additional complications with air quality could be encountered with an experiment involving combustion of tar sand. Such an experiment could potentially release greater amounts of sulfur and nitrogen gases into the atmosphere.

F. "NO ACTION" ALTERNATIVE

The "No Action" alternative is not feasible due to the importance of developing alternative fossil fuel sources in this country. No impacts have been identified which would make the "No Action" alternative preferable. Potential impacts have been identified. Carrying out environmental research along with process research will help mitigate potential impacts as the technology approaches commercial application.

G. MITIGATION MEASURES

The combustion gases from the steam generator will be vented to the atmosphere through a stack directly attached to the equipment. The original dimensions of the stack to be used were two feet by seven feet and ten feet high. Modelling indicated a possible violation of the 24-hr. National Ambient Air Quality Standard for sulfur dioxide (SO_2) emissions. In order to eliminate this potential violation, the State of Utah asked that the height of the stack be raised to five meters or a little over 16 feet to allow for better dispersion of the emissions. To avoid any such violation, LETC will raise the height of the stack on the steam generator to the height requested by the State of Utah.

Additionally, an existing well within the experimental site will be completed to monitor for hot fluid migration through the tar sand formation. This will enable LETC to foresee any potential groundwater contamination.

All production wastes leaving the site for disposal or research will be monitored for date, volume, and destination. Production water and sludges will be analyzed before disposal takes place.

The 5000 bbl. holding pond is lined with a 30 mil CPE lining to prevent leakage from the pond into the surrounding environment.

IV. DESCRIPTION OF THE EXISTING ENVIRONMENT

A. BASELINE CLIMATOLOGY AND METEOROLOGY

1. Climatology

a. Introduction. The tar sand site will be located in a region of gently rolling, high terrain. The climate of the area, and indeed the State of Utah, is governed by its latitude, elevation, location with respect to storm paths over the Intermountain region, and its distance from significant moisture sources such as the Pacific Ocean and Gulf of Mexico.

This section will discuss a variety of climatological parameters as they relate to the area. For purposes of this discussion, climatological parameters are defined to be those not directly related to the development of a dispersion meteorology.

b. Temperature. The continental nature of the area has an important influence upon the climate. The temperature varies considerably from summer to winter due to the presence of cold continental polar air during the summer.

In northeastern Utah, January and July are the coldest and warmest months, respectively. In mid winter, maximum temperatures tend to be near 30°F with minima generally averaging slightly under 10°F. However, temperatures below zero and prolonged periods of extremely cold weather are rare. Surrounding mountain barriers east and north of the state serve to block the intensely cold Arctic air masses from invading the area.

In mid summer maximum temperatures in northeastern Utah tend to average in the low to mid 80's (°F), while mean minimum readings are generally near 50 (°F). Mean monthly temperatures for the Vernal area are shown in Table 6.

Table 6. Mean Monthly Temperatures for Vernal, Utah (°F).

January	16.1	July	69.6
February	23.3	August	67.6
March	34.1	September	58.9
April	45.5	October	47.4
May	54.9	November	33.1
June	62.2	December	21.2
		ANNUAL	44.5

c. Precipitation. Vernal, Utah is not located near any major moisture source. Pacific storms must travel over the Sierra Nevada and Cascade ranges before reaching this area. And in so doing, a large portion of the available moisture has already fallen as precipitation; the result being a relatively dry climate. Summer is the season of maximum precipitation as a result of convective and frontal rainfall. Precipitation records for Vernal are given in Table 7.

Table 7. Monthly Precipitation Normals for Vernal, Utah (inches)

January	0.54	July	0.45
February	0.42	August	0.76
March	0.52	September	0.66
April	0.73	October	0.90
May	0.62	November	0.55
June	0.96	December	0.71
		ANNUAL	7.82

In the area of the proposed tar sand project, annual precipitation averages between 7 and 12 inches per year. A large portion of this total is comprised of rain from summer thundershowers.

d. Sky Cover. Winter and spring are the cloudiest seasons of the year. Winter cloudiness is caused mainly by the presence of large scale storm systems. Springtime cloudiness is caused by the same type of storms which frequent the area in winter, in addition to convective cloudiness which begins to become prominent at this time of year. March is the month with the most cloudiness, while in September cloud amounts are at a minimum for the year.

e. Relative Humidity. The average relative humidity in northeast Utah is quite low. It is related to the rather low amount of moisture. During the warmer part of the summer days, the average drops to about 20 to 30 percent. Late at night when the temperature is lowest, the humidity will generally rise to 50 to 60 percent.

2. Dispersion Meteorology

a. Introduction. A knowledge of the dispersion potential of a region is essential in determining the impact of both ground level and elevated sources of pollutants. Areas that are plagued with poor dispersion conditions for extended periods of time are apt to suffer stringent limitations on land use and industrial development. Under such poor dispersion conditions, seemingly insignificant sources of dust and pollution can result in potentially significant concentrations over large areas. Conversely, areas ex-

periencing extremely good disperion conditions lend themselves to most any type of land development.

b. Seasonal and Annual Stability Distributions. Rock Springs, Wyoming meteorology has been used as the nearest available source of data. The seasonal and annual stability distribution data for Rock Springs are presented in Table 8. This data shows that, on an annual basis, stable conditions occur slightly more than 30 percent of the time. The remaining 70 percent of the annual period is comprised of neutral and unstable conditions with neutral conditions occurring more than three times as often as unstable conditions.

Table 8. Percent Frequency Distribution by Stability Category, Seasonal and Annual - Rock Springs, Wyoming

	Unstable	Neutral	Stable
Winter	6.9	61.7	31.4
Spring	14.7	59.7	25.5
Summer	29.1	35.5	35.4
Fall	14.7	49.9	35.4
Annual	16.4	51.6	31.9

The lowest seasonal frequency of occurrence of unstable conditions takes place in winter when shorter days and decreased amounts of solar insolation reduce the heating of the earth's surface. Unstable conditions occur most frequently in summer when the days are long and solar insolation is great. The highest frequency of occurrence of stable conditions occurs in the summer and fall when a high incidence of clear or mostly clear skies results in a net loss of terrestrial radiation to space at night. The occurrence of neutral conditions peaks in the winter at Rock Springs.

c. Mixing Heights. A typical scenario finds mixing heights to be lowest during the early morning hours due to the presence of a surface or low level inversion. As surface heating progresses during the morning hours, the surface inversion is eroded and finally dissipated. However, an elevated subsidence inversion often exists at higher levels. Thus, as the mixing height increases, it is usually still limited, although to a much lesser degree, by the presence of the elevated inversion. For this reason, mixing heights are generally calculated for both the morning and afternoon periods.

Mean annual morning mixing heights in the study area are roughly one seventh of their afternoon averages. These low morning values are the result of the formation of intense radiation inversions on mostly clear nights. Seasonally, the morning mixing heights do not change substantially throughout the year. Morning mixing heights in spring, however, are slightly higher than for the other seasons. This can be explained by recalling that spring is a

rather cloudy season. Cloud cover restricts the formation of nocturnal inversions acting essentially as a blanket to prevent terrestrial heat from escaping to space thus keeping the surface warm and allowing the mixing depths to increase. In addition, seasonal variations from the annual morning mean are not as great as they are for the afternoon mean.

The isopleths of mean annual afternoon mixing heights show that the values for northeastern Utah are among the highest in the United States. Mixing heights are not as low as they are for coastal areas where maximum surface temperatures are slightly lower due to the nearness of cool ocean waters which inhibit the development of deep mixing layers. They are also not as high as those experienced in areas farther to the south, such as New Mexico, where very low relative humidities lead to mostly clear skies which results in intense surface heating and deep afternoon mixing layers. Afternoon mixing heights reach their peak values in the summer when solar insolation in the region is the greatest, and decrease to roughly one-half of their annual values in the winter. Afternoon mixing heights in the spring are slightly greater than the annual averages while fall values are generally somewhat lower.

d. Air Movement Patterns.

(a) Prevailing Surface Winds. The annual wind analysis for Rock Springs compiled from observations taken between 1968-1977 is shown in Figure 7. This analysis shows that the wind at Rock Springs exhibits a moderate amount of directional variability. In general, however, the preferred wind direction is represented by flow from the west to east with secondary peaks from the south and east-northeast.

(b) Average Wind Speed as a Function of Wind Direction. Rock Springs wind analysis, presented in Figure 8, gives the frequency of occurrence of winds from the 16 cardinal directions. The same data can be seen in tabular form in Table 9. It is also important to examine the frequency distribution of wind speeds from these directions. It can be seen in Figure 8 that the most frequent wind directions are west, west-southwest, south-west, west-northwest, south, east-northeast, and south-southwest, which together occur more than 75% of the time. These wind directions are often accompanied by strong winds (in excess of 21 knots) or moderate winds of 10 knots or more. The strongest winds occur from the west and west-southwest; these are also the most frequent wind directions.

3. Limited Mixing Conditions. In northeastern Utah, though the mean mixing layer wind depth is not at a minimum for the year in winter, the mean wind speed is. In addition, stable conditions occur most often during winter in this area. Since stable conditions, by definition, can only occur at night, these results indicate that the maximum impact on air quality in the vicinity of the proposed experiment will take place during nighttime work in winter since it is at this time that the atmosphere will be least able to disperse surface-generated pollutants.

4. Visibility. Visibility information is available from STAR Data for Rock Springs, Wyoming. There is no applicable visibility standard within the State of Utah at this time. Violations occur when visibilities are less than ten miles and relative humidity is less than seventy percent. Most periods of

Figure 7. Frequency and Occurrence Wind Analysis, Rock Springs, Wyoming.

FREQUENCY OF OCCURRENCE (%)
ANNUAL WIND ROSE

SITE: 24027

FREQUENCY OF CALMS 10.63%

TOTAL WIND SPEED
JAN 68 DEC 77

Figure 8. Annual Wind Rose, Rock Springs, Wyoming.

Table 9. Frequency and Occurrence of Wind Direction, Rock Springs, Wyoming

Annual		Relative Frequency Distribution					Rock Springs, WY 8 Obs 1968-77
		Speed (KTS)					
Direction	0-3	4-6	7-10	11-16	17-21	Greater than 21	Total
N	0.006677	0.010582	0.006267	0.002055	0.000582	0.000068	0.026232
NNE	0.004825	0.007705	0.003596	0.001301	0.000514	0.000240	0.018181
NE	0.006315	0.010993	0.007774	0.007295	0.002705	0.001473	0.036555
ENE	0.006665	0.011473	0.107021	0.017055	0.008082	0.002740	0.063035
E	0.006990	0.011781	0.015685	0.005514	0.001233	0.000171	0.041374
ESE	0.006111	0.101856	0.010068	0.001507	0.000308	0.000034	0.028885
SE	0.006344	0.011062	0.010171	0.002226	0.000274	0.000137	0.030214
SSE	0.004739	0.008425	0.006712	0.003596	0.000753	0.000240	0.024465
S	0.012716	0.023459	0.016473	0.009007	0.005060	0.002021	0.068745
SSW	0.008714	0.025274	0.014284	0.008185	0.004521	0.001610	0.052687
SW	0.010656	0.020548	0.032534	0.014589	0.003630	0.000719	0.082676
WSW	0.017546	0.033014	0.057637	0.050000	0.019623	0.006644	0.184464
W	0.012932	0.025000	0.053596	0.066918	0.040582	0.015788	0.214816
WNW	0.007767	0.015685	0.022705	0.021918	0.010788	0.003390	0.082253
NW	0.004302	0.008082	0.008527	0.004897	0.001644	0.000308	0.027761
NNW	0.003753	0.006096	0.005068	0.001952	0.000719	0.000068	0.017657
TOTAL	0.127055	0.230034	0.288219	0.218014	0.101027	0.035651	

TOTAL RELATIVE FREQUENCY OF OBSERVATION = 1.000001

TOTAL RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE = 0.206267

poor visibility at Rock Springs occur in the spring, followed by winter. However, these violations are minimal and may be attributed to wind blown dust, as wind speeds are typically strongest during these two seasons.

B. AIR QUALITY

The experimental site is located in the Utah Intrastate Air Quality Control Region (AQCR), and meets all the requirements for a Class II attainment area. There are no non-attainment areas nearby. The area has been classified as better than national ambient air quality standards or as "cannot be classified" for suspended particulates, sulfur dioxide, nitrogen oxides, carbon monoxide, and photo chemical oxidants. Specifics on these pollutants are given below.

Total Suspended Particulates	-	better than national standards
Sulfur Dioxide (SO ₂)	-	better than national standards
Nitrogen Oxides (NO _x)	-	cannot be classified or better than national standards
Carbon Monoxide (CO)	-	cannot be classified or better than national standards
Photochemical Oxidants	-	the southern half of Uintah County does not meet primary standards, other areas cannot be classified or better than national standards

There are no mandatory Class I areas within a thirty-mile radius of the site; however, several nearby areas are potential Class I areas that may be redesignated as Class I in the future. These include Dinosaur National Monument (11 miles East), Ouray National Wildlife Refuge (17 miles South), and Ashley National Forest (9 miles North).

C. GEOLOGICAL SETTING AND HYDROLOGY

1. Overall Description

The tar sand research site is located west of Vernal within the Uinta Basin. The northern Uinta Basin is a large structural and physiographic basin consisting of about 5,200 square miles in northeastern Utah and northwestern Colorado. Rocks that crop out in the basin range in age from the upper Precambrian to the Holocene.

The formations that outcrop in the vicinity of the research site are shown on the geologic map in Figure 9. The tar sand deposit is found in the Mesaverde and Duchesne River Formations. Two sandstone layers contain oil: the Asphalt Ridge sandstone layer, at the base of the Mesaverde Formation confined by shale deposits above and below, and the Rimrock sandstone layer, the richest tar sand in the area, found at the top of the Mesaverde Formation. The Rimrock layer is also confined by shale deposits. The Duchesne River

Formation is mainly a conglomerate with boulders up to six inches in diameter having lower and more irregular saturation of oil than zones of the Mesaverde Formation. The field tests for in situ recovery of tar sand are being conducted on the Rimrock sandstone, a fine- to medium-grained and loosely consolidated to unconsolidated sandstone. Figures 4 and 9 show the approximate location of the test site in relation to the outcrop area which occurs about 1/4 mile to the north and east of the test site.

The test zone is in the Rimrock Sandstone Member of the Mesaverde Formation that occurs at a depth of 490 to 540 feet. This 50-foot-thick interval dips southwest at about 28° and is contained on both the top and the bottom by 8 to 10 feet of low permeability shale. The lithology of the tar sand is shown in Figure 10 which depicts the analyses of rock samples from four core holes drilled on the site. In order to illustrate the lithology of the tar sand zone in the vicinity of that small portion of the test site where the steam experiment will be conducted, the well data was projected along a strike of $N70^{\circ}W$ onto a section line drawn through well 3T3 at $N20^{\circ}E$.

2. Surface Hydrology

a. Drainage Basin Description. The test site is located on the divide between the Vernal drainage of the sub-basin of the Ashley-Brush Drainage Area and the Twelve Mile Wash sub-basin of Uinta Drainage Area (Figure 11). Hydrologic data that exists for the Vernal Sub-basin and the water balance is reasonably understood. However, there is apparently no hydrologic data available for the drainage area of Twelve Mile Wash. Therefore, using the Vernal sub-basin as a reference, the following may be postulated for the test site:

- o The normal annual precipitation is about 10 inches per year.
- o The mean annual surface runoff is less than one inch per year.
- o Given the climate of the area, the potential evapotranspiration is expected to be quite high -- probably of the order of 30 inches per year, and the actual evapotranspiration in the neighborhood of 9.5 inches per year.
- o As a consequence of the above three items, the amount of water available to recharge local aquifers is very small.

b. Surface Water Conditions. Ashley Creek, which is four miles northeast of the test site, is the nearest perennial stream. Flow in Ashley Creek is diverted at the head of Ashley Valley for irrigation, and the stream does not become perennial until 1.5 miles east of Vernal where irrigation water returns to the stream bed.

3. Groundwater Conditions

Groundwater is located in the Ashley Valley, an alluvial plain to the east of the site. The LETC site is not located in the alluvial plain or glacial outwash. The alluvial plain has an area of about 35,000 acres and is almost entirely surrounded by older rocks, mainly of Cretaceous age. The aquifer underlying the plain consists of fine to very coarse unconsolidated

Qay	Alluvial deposits	Kms	Mancos Shale
Qgs	Gravel Surfaces	Kmf	Mowry Shale and Frontier Sandstone Members of Mancos
Tbp	Browns Park Formation	Kdcm	Dakota Formation and Cedar Mountain Shale
Tdr	Duchesne River Formation	Jm	Morrison Formation
Kmv	Mesa Verde Group	JRg	Glen Canyon Sandstone
		Ju	Jurassic rocks

Figure 9. Geologic Map of the Uinta Basin near LETC TS-IS Site.

Figure 10. Correlation Diagram of Wells 3T1, 3T2, 3T3, and 3T4 on the Tar Sand Experimental Site.

Figure 11. Hydrologic Sub-Basins in the Vicinity of the Tar Sand Experimental Site.

deposits of boulders and other erosional debris believed to be mainly outwash of glacial origin. The deposits were laid down on a surface eroded mainly in the Mancos Shale of Cretaceous Age. This surface at the base of the valley fill shows that the main source of the eroding water and the subsequent unconsolidated deposits was Ashley Creek above Ashley Valley. This glacial outwash is shown in Figure 9. The principal source of ground water in the Ashley Valley is infiltration of surface water. Minor sources are infiltration of precipitation and subsurface inflow.

Groundwater recharge is closely related to the amount and duration of streamflow into Ashley Valley. The main source of streamflow is Ashley Creek above Ashley Valley. Recharge to the valley fill is derived mainly from infiltration of surface water from the canals and seepage from fields where water is applied along the western and central part of the valley.

The LETC tar sand site is west of the Ashley Valley. As was stated previously, the dip is to the southwest, and the geologic formations outcrop between the LETC site and the Ashley Valley. Therefore, there is no connection between the LETC site and the alluvium water in the Ashley Valley.

The nearest water wells downdip from the LETC site are approximately eight miles to the southwest on the Uintah Ouray Indian Reservation. Those wells are found in the alluvial deposits along the Uinta River and its tributaries. As in the Ashley Valley, recharge is derived mainly from infiltration of surface water and from fields where water is applied.

Based on this information, it can be concluded that the TS-1S experiment will not impact groundwater in the glacial outwash and alluvium to the east or west of the site. The alluvium on-site is insignificant as a water course due to low rainfall, high evapotranspiration and remoteness from surface water.

The Duchesne River Formation overlays the Rimrock sandstone. The nearest wells that use the Duchesne River Formation are eight miles to the southwest on the Uintah Ouray Indian Reservation where the glacial alluvium overlays the Duchesne River and Uinta Formations. Two miles southwest of the site the hydraulic conductivity has been measured to be 0.002 ft/day. Hydraulic conductivity of 0.5 ft/day is considered to be very low.

The tar sand resource is found in the Mesaverde Formation. The oil-bearing beds have a water-wet matrix. However, no mobile water has been found on site.

Below the Mesaverde Formation is the Mancos Shale Formation. This formation has very low permeability.

Core data on site indicates that shale overlays and underlays the target tar sand within the Rimrock tar sand. This shale will prevent transport to either the relatively dry alluvium or the underlying Mancos Shale.

D. BIOLOGICAL

1. Aquatic

The in situ tar sand experimental site operated by DOE near Vernal, Utah, will not adversely affect aquatic biota which inhabit the lower Green River.

Because of the small size of the project, containment measures initiated, and the relatively long distance to any perennial body of water, no adverse impacts upon this aquatic habitat are anticipated.

The experimental site is arid and has no aquatic habitats within its boundaries.

2. Vegetation

a. General Description. The tar sand deposits pertinent to LETC's research endeavors near Vernal, Utah, are located under vegetation types characteristic of those found within the Great Basin, and specifically those found within the Uinta Basin, a depression of the Green River Formation.

Shrubland, juniper stands, and riparian vegetation typify the area around the existing research site. The shrub communities are typical of those described by Harrington (1964) and his semi-desert area and Nelson's (1897) cold desert shrublands. Juniper stands occupy the higher plateau areas and can be found on the slopes of ridges and lower drainages of perennial or intermittent streams. Riparian communities occupy narrow stretches of lowlands along perennial streams or as induced communities from irrigation projects.

This vegetation pattern is an end result of the climate of the region. Less than 10 inches of moisture falls annually, most in the form of snow during the winter months. Moisture falling during the growing season results from localized thunderstorms. The moisture most often leaves as surface runoff and is not available to resupply soil moisture for plant growth. Consequently, snowmelt and spring snowstorms and rains during March and April are most important in sustaining the existing vegetation by providing both surface and deep soil moisture reserves from year to year.

Four broad vegetation types exist in the area surrounding the tar sand research site. These include Big sagebrush (Artemisia tridentata), Black greasewood (Sarcobatus vermiculatus), Utah juniper (Juniperus utahensis), and riparian.

The entire 10-acre research site is located within Big sagebrush vegetation type and the stand surrounding the site reveals that the shrub is homogeneous. The plants are approximately 2 feet in height, and new seedlings are not evident, indicating a closed sagebrush community. This sagebrush type gives way to the juniper stands along the upland on which the research site is located, and then continues to the north to where irrigation takes place. To the west and east it again gives way to the juniper type. It continues to the south as the dominant vegetation type. No mapping of the distribution of vegetation of surrounding or site-specified land for documentary purposes has taken place.

Juniper stands are prevalent near the study area, occupying portions of Asphalt Ridge to the west and along the eastern slope of the upland on which the research site is located. This type has not been mapped since it is not part of the research site.

Riparian communities lie to the north and east of the research site and are represented by croplands under irrigation and native plant associations

along the Green River and other perennial streams. Riparian communities have not been mapped since they are not part of the research site.

Black greasewood is a salt-tolerant shrub and occupies deep soils within lowlands, flats, and along the bottoms of deep draws and canyons where saline conditions occur. No associations of greasewood are located on or in close proximity to the research site. It becomes a dominant type to the south of the study area. This type has not been mapped since it is not part of the research site.

b. Rare and Endangered Species. Comparison of the 1974 species list above with "Threatened or Endangered Fauna or Flora" (USDA, Fish and Wildlife Service, 1975) indicates no rare or endangered plant species occur within the native range of the tar sand research site. The plants listed are characteristic of the Big sagebrush vegetation type. Plant collections normally are updated as research continues on specific research sites. There is a possibility, because of their rare occurrence and chance of being overlooked, that rare and endangered species may be found. If this is so, verification and notification will be carried out.

3. Terrestrial Fauna

a. Introduction. Inventories on the type of terrestrial fauna found in the region are available upon request. These inventories are of a regional nature and do not indicate the presence or absence of any species upon the site, only their possible presence.

b. Rare and Endangered Species. The only rare or endangered species that might appear in the region and in a sagebrush habitat type are the American Peregrine falcon, the Black-footed ferret and the Utah prairie dog. All three of these animals are classified as endangered by the U.S. Department of the Interior, Fish and Wildlife Service. The status of the Peregrine falcon and the Utah prairie dog within the region are not known at this time. Utah is on the extreme western portion of the Black-footed ferret's range, and they never existed in great numbers in the state. There have been three unconfirmed sightings in the eastern portion of the state in recent years, however; two were in the Uintah Basin and one was near Green River, Utah (Utah Division of Wildlife Resources, 1976).

The Utah Division of Wildlife Resources lists no animals that would be found in a sagebrush habitat as endangered. They do list the Bobcat, which is a common visitor and, if conditions are right, a resident of the sagebrush habitat, as declining. The Bobcat is not protected at this time but may be in the future.

E. AESTHETIC, RECREATIONAL, AND CULTURAL

1. Known Cultural Resources

No archaeological or historic sites are known from the immediate vicinity of the proposed experiment station. The site itself was surveyed for cultural sites by Mr. Curt Tucker of the Vernal District of the Bureau of Land Management, who reported an absence of sites.

2. Potential Cultural Resources

Within the immediate experimental area no sites were found after a complete inventory. Because of the lack of water near the experiment site the probability of sites in the immediate locality is low.

3. Aesthetic Value

Lying close to Utah Highway 121, the site can be seen, but it is not in full view of the roadway. The site has less than 20 feet of relief and is not impressive topographically. A 40-acre tract near the experiment area has been stripped for gravel by local construction firms. A Utah Power and Light transmission line also passes adjacent to the site. No perennial drainages exist within several miles of the site. The site itself would not block a view of surrounding terrain as seen from Highway 121.

Vegetation on site consists of low desert shrubs and grasses. The site is in no way distinctive from an aesthetic viewpoint, and is already partially altered.

4. Recreational Opportunities

Recreational opportunities are greatly restricted at the site. The land is privately owned so access is determined by the landowner. Big game animals are rare, with mule deer being the only occasional transient. Small game is present but estimates show less than 12 hunter days per year spent there.

No water is on or near the site so waterfowl hunting, boating, fishing, and swimming are not possible. The land ownership status could limit access for motorcycling or 4-wheeling and hiking.

F. SOCIOECONOMIC ENVIRONMENT

Utah is not a heavily populated state. Averaging 14.1 people per square mile it had a population of 1,065,000 in 1970. This represents over a 100 percent increase from a 1930 population of 509,000. Uintah County averages 2.83 people per square mile and had a 1970 population of 12,684. Vernal, the population center for Uintah County, had a 1974 population of 5,000. This represents only 32.89 percent of the total county population.

With the current emphasis on energy development, the recent approval of an oil shale project in Colorado, and the possibility of the Central Utah Water Project being funded, it appears that the Uinta Basin will have to contend with an increasing population. Oil shale development in the region will undoubtedly have an effect on Vernal and Uintah County as well as the Uinta Basin as a whole. If oil shale deposits in the basin are developed, we can expect the population increase due solely to oil shale to peak at around 13,780 then level of the 12,535 in the second phase of the commercial stage.

V. ENVIRONMENTAL CONSEQUENCES

A. AIR QUALITY

1. Pre-Operational Phase

Air quality would deteriorate during the construction phase due to two sources of emissions: exhaust gases from transportation and construction

vehicles, and fugitive dust created by earth moving and vehicles. Because of the small size of the research projects, with only about 10 vehicles per day contributing to the pollution, the impact is not considered to be serious.

2. Operational Phase

Air quality would deteriorate more seriously during the operational phase of the research project. Emissions and dust due to vehicular use would continue, and additional amounts of air pollution would be created by well-boring equipment and by venting of the gases produced by the process.

The vented combustion gases from the steam generator constitutes probably the largest steady source of emissions. Air quality problems are anticipated only in the immediate vicinity of the stack on the generator. The gaseous emissions from the stack are typical of combustion products from fossil fuel in the presence of excess oxygen.

Initial modelling of stack emissions using the PTMAX Model indicated a possible violation of the 24 hour standard for sulfur dioxide (SO_2) emissions. No violations were indicated for nitrogen dioxide (NO_2), particulates, hydrocarbons (HC), or carbon monoxide (CO).

More in depth modelling was performed using the EPA Valley Model which indicated violation of the 24 hour standard for SO_2 . The 24 hour results were obtained using assumed worst case meteorology of E Stability, wind speed of 2.3m/sec., and a ten foot stack height.

By raising the stack height to five meters, the possible violation of the 24 hour SO_2 standard was eliminated. Copies of the computer printout from the EPA Valley Model are available on request. Table 10 shows a comparison of worst case annual sulfur dioxide concentrations at various stack heights. These values were compared with the annual arithmetic mean concentration standard of 80 micrograms per cubic meter.

Table 10 - Stack Height Versus Annual Sulfur Dioxide Concentrations Under Worst Case Meteorological Conditions¹

Stack Height	$[\text{SO}_2] \mu\text{g}/\text{m}^3$
3 m	98.10
5 m	74.60
10 m	58.96

¹ 24-hour results were obtained using assumed worst case meteorology of E Stability, wind speed of 2.3 m/sec, and the above stack heights.

Dust and exhaust emissions should be short-term and small in quantity. The gas emission from the generator will continue for the duration of the experiment (six to twelve months). No cumulative impacts are anticipated.

3. Post-Operational Phase

Short-term impacts include engine exhaust and dust created by earth moving and vehicular operation during the restoration process. These short-term impacts can be reduced by surface treatment of dust-producing areas and by scrubbing and particulate separation of the cooling water products, if warranted. No long-term or cumulative impacts are anticipated.

It should be noted that no reference to possible accidental releases of air pollution could be found in the project description. Some assessment of this possibility is warranted, especially in view of the anticipated large-scale development. For example, accidental explosion and burning of the surface-stored oil could produce a large amount of pollution, substantially greater than the stack emissions. Perhaps the possibility of accidents is nonexistent, but the extent of the possibilities should be assessed.

B. WATER QUALITY

1. Pre-Operational Phase

In preparation for recovery experiments, land is cleared of vegetation, topsoil is removed and stockpiled, and gravel is placed over the area of activity. The present research site has 10 acres fenced of which about 6 acres are cleared. Access roads are graveled. Tanks for containment of produced oil and water have been placed in a pit that has been excavated several feet and the excavated material has been used as a dike around the pit to contain accidental spills. Several small buildings have been erected or moved onto the site.

One of the effects of these changes is to increase the imperviousness of the area, thereby increasing rainfall and snowmelt volumes and peak flows, plus increasing erosion and sediment, and dissolved solids delivery downstream. These impacts are insignificant on the present research site because the site is small and on a broad ridge where the land is even and nearly flat. In addition, a small dike has been constructed along the lower end of the site to contain runoff and sediment.

2. Operational Phase

Surface conditions during operations are the same with regard to surface runoff as were described for the pre-operational phase above.

Groundwater quality will not be affected during the operational phase. The tar sand formation contains no mobile water. The formation is contained above and below by shale which has a low permeability. Groundwaters in the area are associated with the alluvium several miles east and west of the site.

Clean water which has been run through a steam generator will be injected. An unknown percentage of water will remain in the tar sand zone. They will be monitored for migration and movement away from the affected area. Thus, a groundwater monitoring program will be established to detect any migration or movement of this water away from the affected area to determine means of preventing groundwater contamination.

3. Post-Operational Phase

Following production at the site, the area will be restored to its original conditions as nearly as possible. After revegetation, the surface hydrological conditions should be nearly the same as those prior to development.

Groundwater studies will continue after the experiment to determine communication problems in the formation.

C. WASTE DISPOSAL

The LETC TS-1S steam injection experiment must dispose of both solid and liquid wastes. Solid wastes will be hauled to a nearby licensed disposal facility by LETC or contract employees. The solid waste will consist of wood, paper products, glass, and other miscellaneous items.

Sanitary wastes generated by on-site employees will be handled by a septic tank and leach field system.

1. Pre-Operational Phase

All wastes generated during the pre-operational phase will be removed from the site to the Vernal city dump by LETC or contract employees.

All sanitary wastes will be handled by the on-site septic system.

2. Operational Phase

Solid and sanitary wastes will be handled in the same manner as during the pre-operational phase as previously discussed.

The production recovered from the tar sand formation is expected to be a water-oil emulsion, similar to those recovered from laboratory tests and the steam injection test (LETC-SIT). The product will be treated with Tretolite F-46 or other demulsifier at concentrations from 250 ppm to 2000 ppm depending on the success of the demulsifier agent.

Recovered water in the holding tank will be recycled through the steam generator if possible. That water which cannot be recycled will be hauled away by licensed commercial haulers and disposed of at the Vernal city dump.

3. Post-Operational Phase

All solid and sanitary wastes will be disposed of as previously discussed in the pre-operational section. All excess production water will be removed to the Chevron waste pit by licensed commercial oil field service companies.

D. BIOLOGICAL

1. Aquatic

a. Pre-Operational Phase. Problems such as dewatering or channelization are not foreseen for the in situ tar sand project near Vernal, Utah,

as LETC has no plans for physical alteration of area streams or lakes. The site is arid and situated approximately 3.5 miles from the nearest perennial water source and 13 miles from the nearest downstream perennial water.

Adequate sediment containment during construction of the site by contouring to near-level surfaces, initiating settling basins for drilling operations to hold drilling mud, water, and debris on site will mitigate sediment loading of streams, thereby preventing degradation to aquatic habitats through erosion.

Oil, gas, and chemical spills from construction, drilling, and fracturing activities represent potential toxic materials of the pre-operational phase. Impact from these toxic materials will be small and localized on-site since the site is located in arid land and is only 10 acres in size.

b. Operational Phase. Measures taken to minimize the impact of site activities on the aquatic environment have been described in the previous section. Other sources of pollutants such as the steam generator and vehicle traffic are not considered to be adversely affecting aquatic habitats.

Toxic materials and salinity associated with the oil and water produced by the in situ process are considered to be primary factors which could affect the aquatic biota of area waters. Since contaminants are not released in the ongoing research and the site is arid, no significant impacts are expected.

The wastewater is ultimately disposed of in the liquid waste disposal area of a landfill dump or held for research. Water produced from the tar sand research site is not able to reach the distant aquatic habitats through surface water.

c. Post-Operational Phase. Possible long- and short-term impacts during the post-operational phase include erosion and sediment deposition, gas escapement, and aquifer contamination. Proper revegetation and site reclamation will prevent excessive erosion and sediment deposition in aquatic habitats. The present site is small, so impacts will be minimal.

Groundwater transport of toxic and saline materials from the underground retort site is very unlikely due to the isolated nature of the site. The arid land and isolation from perennial and intermittent water sources should effectively prevent contamination of lakes or streams by liquid effluent through the groundwater.

2. Vegetation

a. Pre-Operational Phase. The major impact on vegetation during construction will be surface disturbance and removal of vegetation. Shrubs characteristic to the arid lands within the Vernal area and utilized by livestock and wildlife for grazing will be lost for a lengthy time after reclamation. No critical habitat will be lost. Topsoils are presently being stockpiled for reclamation purposes. The impact site will be minimal for research operations.

b. Operational Phase. The critical impact on vegetation during the operating phase will arise from chemicals produced by in situ recovery of tar sand bitumen. The significance of the potential toxins is not known at this time. It is expected that in situ produced water will be toxic to plants and to other organisms in the soil. In situ water is produced and contained in quantities conducive to laboratory and field research within the dry and isolated site near Vernal. No production water will contact the surrounding lands.

c. Post-Operational Phase. Short-term impacts and risks associated with in situ development of tar sand during the post-operation phase include:

1. Surface disturbances from the removal of equipment.
2. Abandoned roads.

Surface disturbances from the removal of equipment and facilities will be minimal, as will the effects of abandoned roads on vegetation. Site preparation during the construction phase will have removed the native flora. Only those plants invading the scraped and compacted surface near the facilities and those growing in the roadbed are subject to destruction. Annual species described earlier will be the dominant plants. These species are undesirable for revegetation and will be eliminated during mechanical treatment of the post-construction surface disturbances for seedbed preparation. No doubt they will again occur in association with the seeded species chosen for reclaiming the site.

3. Terrestrial Fauna

a. Pre-Operational Phase. The site near Vernal is only 10 acres and this small loss of habitat should have little effect on wildlife of the area. Small rodents that have home ranges restricted to the site will be lost, while larger mobile species will move away. The vast area of sagebrush habitat will allow the displaced animals to relocate without a great deal of stress or competition with those animals already living in the off-site areas. This small experimental development will not disrupt intensive use areas or migration routes.

b. Operational Phase. The short-term impacts of the operational phase would be much the same as those of the construction phase. The impacts of traffic, noise, and dust would still be present. Indiscriminate killing of animals and collisions with vehicles could still be a problem. Oil spills could cause impacts on local populations.

Some air pollution of a temporary nature would result from vented combustion products of produced gas, but the gases vented would comply with state and federal air quality control standards.

c. Post-Operational Phase. Short-term impacts will diminish as operations cease. Long-term impacts, such as loss of habitat, will take time to be negated. Even with revegetation, time will be required for the site to become a stable vegetative community again. As the disturbed area returns to its native vegetation type, wildlife usage will increase.

Effects from possible air pollution would diminish after production is halted. There could be lingering effects seen in those plants and animals affected during production.

If groundwater systems were disturbed during the operations they could remain in the disturbed state long after production has ceased.

E. SOCIOECONOMIC ENVIRONMENT

1. Pre-Operational Phase

Because the tar sand project was initiated in 1974 the site construction has already taken place. Socioeconomic impacts would be insignificant with such a small project being constructed. This is especially the case for a town with a sizable tourist trade where there are numerous motels and restaurants for the LETC personnel to use when working at the tar sand site.

2. Operational Phase

It has been estimated (Bureau of Mines, 1974:21) that project personnel would range from 8 to 12 men, although more recent LETC estimates range from 6 to 20 men. Using the range of 6 to 20 workers, we do not predict any perceptible socioeconomic impacts on Vernal and the surrounding area. Twenty additional people in the area will go virtually unnoticed.

3. Post-Operational Phase

We expect the greatest amount of socioeconomic impact to come with population increases. Since the tar sand site operates with such a small number of people (6-20), we do not expect any significant impacts upon their leaving the area.

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